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The Impact of Government Support of Graduate Schools on the Research Productivity of Professors and Students†

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This paper examines the effects of major funding projects for graduate education in Korea, specifically the BK21 and the WCU programs, on the research productivity of professors and young researchers. We apply the standard DID method, which compares the increase in research outputs as measured by papers per year between groups before and during the project period. The DID estimates show that the effects are quite different for different fields, but they mostly indicate that the BK21 project is more effective in terms of the research productivity of the participating professors, especially those who study science and engineering areas. With regard to the productivity of graduate students, the results show that there was an increase in the research productivity of locally educated Korean doctoral degree holders after the graduate funding programs, mainly in natural science and engineering fields.

Key Word: Research fund, Research Productivity, BK21, WCU
JEL Code: I23, H52, J44

I. Introduction

This paper examines the effect of government research grants to graduate schools on the research productivity of professors and graduate students using an individual-level dataset derived from the National Research Foundation of Korea. From the late 1990s, the Korean government attempted to establish world-class research universities by giving unprecedentedly large amounts of research funds to a few selected universities. The most notable funding programs are the Brain Korea 21 (henceforth, BK21) project, which started in 1999, and the World Class University (henceforth, WCU) project, which started in 2009. These two programs applied very different funding schemes. In the BK21 project, most

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research funds were given to graduate students in the form of grants. In the WCU project, much of the research funding was used to promote international academic cooperation, mainly by inviting renowned scholars from abroad, including some Nobel Prize laureates. Also in the WCU project, research teams are encouraged to open a new department or a program inside a department.

This contrasting feature of the funding schemes provides us a rare opportunity empirically to evaluate the effects of different research funding schemes on the productivity of major researchers in the receiving university, i.e., professors and graduate students. When we investigate the research productivity of professors, we compare the research outputs between two treatment groups, which consist here of participants of the BK 21 and the WCU projects, and a comparison group, which consists of top researchers among non-participants. We applied the standard DID method, which compares the increase in research outputs as measured by the number of papers per year among these groups, before and during the projects. From this investigation, we attempt to evaluate the efficiency of the two different research schemes for different academic disciplines.

With regard to the research productivity of students, we compare the research productivity of Korean doctoral holders who earned their doctorates in Korea and those who received theirs in the USA, which is widely believed to have the best graduate programs in the world in many academic disciplines. Again, we applied the standard DID method, which compares the annual production of papers of these two groups of doctoral degree holders before and after the BK 21 project.

If we recognize that the research productivity of professors and graduate students is a good proxy for the quality of graduate schools, we can expect to find evidence from this empirical investigation with which to determine whether the government funding for the graduate studies had any positive and/or significant effects on the quality of the graduate studies. In addition, we attempt to evaluate the relative efficiency of contrasting research funding schemes for different academic disciplines, thereby to draw policy implications which can inform the creators of better research funding schemes.

The remainder of this paper organized as follows. In section II, we briefly review the related literature. Section III explains the institutional backgrounds. Section IV introduces the dataset and the framework of the empirical investigation. Section V presents the empirical results and discusses their policy implications. Section VI concludes the paper.

II. Literature Review

There are not a few empirical studies on the research productivity. Recently, Aksnes (2012) provided an extensive literature review of the scientists' research productivity levels,[1] documenting that demographic factors such as age and gender

[1]This review is not confined to the economics literature. It is only natural that researchers in any field have much interest in research productivity, and there is indeed a large body of literature with authors from various academic fields. However, it should also be noted that economists' analyses employ the most rigorous statistical methods.

are closely related to research output. With regard to age, although the results of previous studies have not always been entirely consistent, it is quite firmly established that there is a quadratic relationship between age and productivity. This pattern has been found across many fields and nations. For example, in the economics literature, Levin and Stephan (1991) find that life cycle effects are present in physics and earth sciences, Goodwin and Sauer (1995) find similar effects of age on research output in economics, and Oster and Hamermesh (1998) find that economists' productivity levels over their careers as measured by publications in leading journals declines very sharply with age. With reference to gender, many studies have shown large gender differences in scientific productivity levels.

The availability of resources, both in terms of financial support and human resources, affect research productivity as well. Kyvik (1991) reports that scientists who have more graduate students and technicians tend to be more productive that those who do not have as many supporting staff members.[2] As we will see later, one finding of this paper can be explained in line with this observation.

Institutional or organizational characteristics can also affect research productivity. For example, according to this review, many studies have shown that the productivity of publications at individual levels tends to increase within the hierarchy of academic positions. Some studies find that such factors as the department climate, age structure, and a higher level of freedom are correlated with publication productivity, though it is difficult to establish a causal relationship. One can argue that rather than favorable institutional characteristics affecting the productivity of an individual, a productive individual is more likely attracted by such institutions.

Meanwhile, there are not many empirical studies of the relationship between funding and research output, especially at the individual level. Some studies find weak positive relationships between research funding and outputs for different academic disciplines. Averch (1988) estimates the determinants of citations per dollar of NSF funding for a random sample of 93 projects in chemistry. He finds only a very modest relationship between citations per dollar and the characteristics of the principal investigators' affiliated institutions, although their characteristics do have some impact on citations per dollar. By contrast, for behavioral and neural sciences, Averch (1987) finds that even principal investigators' characteristics are unrelated to citations per dollar.

Aroma and Garmbrardelia (2005) find that NSF funding has only a modest effect on publication output, using dataset of 1473 applications for NSF in economics during 1985-1990. More recently, Jacobs and Lefgren (2011) estimate the impact of receiving a NIH grant on subsequent publications and citations. They find that receipt of a NIH research grant leads to only one additional publication over the next five years, representing only a 7% increase. Their interpretation of this small effect is that the loss of NIH grants simply causes a shift to another source of research funding in the presence of many alternatives. Methodologically, this study

[2]Aksnes (2012) explains that this is due to the fact that students and technicians will do much of the time-consuming data collection and data analysis work, and that supervisors may become coauthors of publications mainly written by graduate students and research associates.

uses a rich dataset that includes information about successful and unsuccessful applications while also attempting to handle the issue of selection bias.

With regard to empirical analyses of Korean graduate funding projects, we find very few. A monograph by the RAND Corporation (2008) points out that the net effect of BK21 on human resources and national R&D capacity building “compared to other projects” remains unverified. This monograph presents the conceptual framework by which the BK21 project is evaluated in detail, but empirical analyses and results are not presented.

Kim (2015) empirically examines the effect of the Brain Korea 21 project on the research productivity of participating professors, finding that for many in the science and engineering fields, the effects are positive and significant, whereas for most in the humanities and social sciences fields, the effects are insignificant or even negative. He interprets these results as evidence that grants to graduate students can be an effective means of increasing the research productivity of professors in some fields that require extensive experiments and help from research assistants.

This paper extends Kim’s (2015) analysis in two directions. First, it includes another major graduate funding project. Second, it includes an analysis of new doctoral graduates’ productivity levels in the evaluation of the effect of funding on educational quality levels.

III. Institutional Background: BK21 vs WCU

The first phase of the BK21 project started in 1999, as a seven-year project. After the first phase, the second phase of the project started in 2006. Like Phase I, the main purpose of this phase was to foster world-class research graduate schools in various academic disciplines. To achieve this policy goal, the program was designed to provide most of the research funds to graduate students and young post-doctoral scholars. The fund beneficiary unit is the research group, which consists of professors, post-doctoral researchers, doctoral students, and master students. To gain BK21 funds, a research group should apply for funding by submitting the group’s research proposal to the National Research Foundation of Korea (henceforth the KRF). The KRF reviews and evaluates the proposals and then selects research groups in each field.

There are several important restrictions when applying for BK21 funding. First, a research group should consist of more than 70 percent of faculty members in departments that have a doctorate program with enrolled doctoral candidates. Second, the number of faculty members participating in the research group must exceed seven for humanities and social sciences groups, ten for basic science groups, and ten to twenty five for applied science groups. In addition, all of the participating professors should produce more than the minimum average number of publications for the prior three years. The selection criteria are related to the issue of a comparison group, as discussed below. Third, all research groups must secure matching funds from their universities, which must be greater than five percent of the level of BK21 funding from the government. All of these preconditions are favorable to large research universities with relatively large research funds.

BK21 recipient research groups are selected at the beginning of each seven-year phase.[3] A very unique feature of the BK21 funding scheme is that, although the largest portion of it is used for scholarships and stipends, individual recipients are not selected on their own merit. The award selection criteria are based on the qualifications of the research group to which the individuals belong; the excellence of their department; and to their university's commitment to the department, institutional reform, and research infrastructure. However, the most important selection criterion is the research ability of the participating professors. There have been annual evaluations of research groups, and in a few cases, some groups were eliminated from the project. To fill the vacancy, a new research group comes in, again after the selection process.

The amount of BK21 research fund is approximately 280 million US dollars annually. The seven-year total amounts to nearly two billion US dollars. Each research group has little discretion in managing the research funds in that there are important restrictions. Table 1 presents the major spending items and restrictions on spending. The major spending item is grants to young researchers, including graduate students and post-doctoral researchers. Other than grants, there is a category termed "international cooperation, with funds usually spent on hosting or participating in international academic conferences. The operational cost includes incentives for professors (less than 300 US dollars per year), salaries for assisting staff members, and other minor expenses such as conference registration fees and the publication fees. The lack of a pecuniary incentive for professors is another important aspect of the BK21 project.

It should be noted that while international cooperation was encouraged, such collaborations did not widely occur. Participating in an international conference has been the major form of the international cooperation, and inviting world-class scholars was rare and there have been few, if any, continuing relationships. This is one of the reasons why the Korean government decided to launch another project, the WCU.

TABLE 1—BUDGET ITEMS OF BK 21 PROJECT

Category	Major Spending Items	Prohibited Items
Grants to Students	◦ Master (more than \$500 per month) ◦ Doctoral (more than \$900 per month per student)	◦ More than the maximum amount set by the government ◦ More than 30 days of overseas training
Grants to New PhDs	◦ Post-doc: more than \$2000 per month ◦ Part-time professor; More than \$2500 per month	◦ More than the maximum amount set by the government
International Academic Cooperation	◦ Participating in International Conferences ◦ Inviting World-class Scholars	◦ Fees for professors (when the sole participant) ◦ Passport, Visa fees, etc.
Operational Costs	◦ Incentives for professors (less than 300 dollars per year) ◦ Salaries for assisting staff members ◦ Conference registration fees, publication fees, etc.	◦ Land, buildings, etc. ◦ Equipment facilities ◦ Consulting fee for participants ◦ Patent-related fees for individuals, etc.

[3]As of 2012, the second phase had ended. In the third phase, the program will continue. The second phase ended in 2012. The third phase, another 7 year project, started from the next year with the project title "BK21 Plus".

Before comparing the two projects, let us briefly review some important financial restrictions applied to these projects. In the case of the BK21 project, grants to students should be more than 60% of the total funds in the natural science and engineering fields endowed to graduate students. The maximum portion is 72%. Grants to young post-doctoral scholars account for another 20% of the total budget. From the perspective of professors, nearly 80% of research funds go to supporting staff. The remaining 20% go for international academic cooperation and operational costs. Participating in international conferences is very much encouraged, but funding is given only when professors are accompanied by students and young post-doctoral researchers.

As of 2010, there were approximately 400 research groups in the natural sciences and engineering areas. On average, 500 thousand US dollars are given to each research group. The financial restriction is observed well by the participating research groups. On average 63% of funds were given to graduate students in 2010. Nearly 20% were given to post-doctoral scholars. In addition, approximately 12% of funds are allotted for international academic cooperation on average, and operational costs take another 8%.

In the humanities and social sciences, the research groups are generally smaller in terms of funding. The total funding for each research group is about 250 thousand US dollars, which is about half of what the science and engineering field receives. Similar to the science and engineering field, more than 80% of the funds were given to graduate students and post-doctoral scholars.

In terms of financial restrictions, the WCU project is quite similar to the BK21 project. Most of all, the recipient unit is identical; specifically, a research team is composed of professors and graduate students and post-doctoral researchers, but it has a different funding scheme from the BK21 program. There are three types of research teams in the WCU program. In type 1, funds are given to research teams that create a new department or a distinct program inside the department. Type 2 funds are given to research teams which invite a foreign scholar and work with him/her. For type 3, very much similar to the second type, funds are given to research teams that invite renowned foreign scholars, usually Nobel Prize winners or strong candidates, and work with him/her. There is a common factor between the BK21 and WCU programs in that the funds are given to research teams composed of professors, students, and new doctoral researchers. However, in the WCU program, international cooperation was greatly emphasized, and it is possible to have smaller teams.

The funds for WCU projects are divided into three categories. For each research team, grands to students or foreign scholars account for the largest share, at more than 40% of the all funds. The research infrastructure, including laboratories and equipment, is allocated another 40% as well. The remaining 20% pays overhead costs. As a result of the WCU project, 34 new department or fields were established and 288 foreign scholars were invited. As the project emphasizes international cooperation, many English courses are offered: 242 out of 302 new courses. Table 2 summarizes the key features of the BK21 and the WCU projects.

TABLE 2—COMPARISON OF THE BK21 AND THE WCU PROJECT

	BK21	WCU
Purpose	Providing research funding to a group of researchers to enhance the quality of post-graduate education, thereby fostering world-class graduate programs	Enhancing research productivity in some key academic fields, and fostering the next generation of researchers. Providing a new research environment through cooperation with foreign scholars.
Unit of Recipients	Research group or team	New department or new major within the department (type 1) Research team with individual foreign scholar(s) (type 2) Inviting world-class scholars (existing department, type 3)
Duration	Seven years, 2006-2012	Five years, 2008-2012
Number of Recipient Units	58 research teams in the humanities and social sciences (41 teams from the national competition and 17 from local-based competition) 150 research teams in the natural sciences and technology (94 teams from the national competition and 56 from local-based competition)	34 departments or fields (type1), 43 research teams (type 2), 46 research teams (type 3), A total of 123 new departments or research teams
Funding Levels	Total: \$200 million (2011), \$30 million for social sciences and humanities \$170 million for natural sciences and engineering \$400,000 for each unit on average, and \$900,000 for each unit on average for natural sciences and engineering	Total: \$140 million (2011) \$2.9 million for type 1 \$800,000 for type 2 \$180,000 for type 3

IV. The Data and the Empirical Framework

A. *The Data*

The basic dataset comes from the BK21 and WCU databases. Each research team reports basic information, such as the number of research members and their publications, to the National Research Foundation of Korea (Henceforth, the KRF). The KRF gathers the information and manages the database. Accordingly, the BK21 and the WCU datasets have detailed information on the research output of the professors participating in the program.

Yet without information about a proper comparison group, specifically a group of researchers who do not participate in the project but with comparable research abilities, a strict evaluation is not possible. To compose a control group, we also used a dataset drawn from the KRF's researcher database. This dataset has information about the research output of individual researchers who agreed to allow their information to be made public. Approximately 15% of the researchers agreed to reveal their information about their research output. The dataset is based upon this 15% sample.

In Korea, every new doctoral recipient is supposed to register with the KRF online. Once registered, the information is updated whenever researchers report their research outputs to the KRF online. For a published paper, they report the title, the year of the publication, the name of the journal, and the number and names of any co-authors. They also report if the paper was published in science citation index (henceforth SCI) or in social science citation index (henceforth SSCI) journals. In this paper, we only count papers in SCI or SSCI journals as those published in an international journal. Likewise, we only count papers published in the Korean citation index (henceforth, the KCI) journals as cases of a national journal.[4] There is some verification process on the part of the KRF to check if the researcher's report is correct. This takes some time; accordingly, there is a possibility of some measurement error in the number of published papers, especially in recent years.

Before discussing the control group, we consider the differences in research outputs among different fields. Comparing the research productivity levels of different academic disciplines has practically no meaning, especially when we measure productivity in terms of the quantity of the output, as in this paper. Let us look at examples.

Table 3 shows the average number of annual publications per researcher for certain science fields from 1995 to 2010. When calculating the number of publications, we assign a value of 1 for a single-author paper. When there are two or more authors, we assign a value of 0.5 when the researcher is the first or the corresponding author. Otherwise, when the number of authors is n, we simply assign this case a value of 1/n. In this manner, we can calculate the number of papers produced by each researcher in a specific year.

We present the number of papers per researcher in SCI and KCI journals. From the table, two aspects are immediately noticed. The first is that the research productivity of Korean scholars has increased in every science field from 1995 to 2010. For example, the average number of papers in SCI journals in physics was

TABLE 3—ANNUAL AVERAGE PUBLICATIONS PER PERSON IN SCI JOURNALS (NATURAL SCIENCES)

	Annual publication per person				Ratio (Math=1)		
Year	Math	Physics	Chemistry	Biology	Physics	Chemistry	Biology
1995	0.069	0.277	0.222	0.116	3.99	3.21	1.67
1996	0.104	0.308	0.242	0.148	2.96	2.33	1.42
1997	0.134	0.396	0.337	0.138	2.96	2.52	1.03
1998	0.160	0.454	0.297	0.194	2.83	1.86	1.21
1999	0.151	0.512	0.339	0.184	3.39	2.25	1.22
2000	0.202	0.612	0.367	0.247	3.02	1.81	1.22
2001	0.260	0.666	0.450	0.268	2.57	1.73	1.03
2002	0.255	1.093	0.675	0.393	4.29	2.65	1.54
2003	0.458	1.440	1.077	0.637	3.14	2.35	1.39
2004	0.520	1.328	1.084	0.817	2.56	2.09	1.57
2005	0.643	1.545	1.239	0.761	2.40	1.93	1.18
2006	0.589	1.515	1.277	0.834	2.57	2.17	1.42
2007	0.775	1.547	1.498	0.982	2.00	1.93	1.27
2008	0.733	1.653	1.620	1.087	2.26	2.21	1.48
2009	0.862	1.608	1.740	1.155	1.87	2.02	1.34
2010	0.883	1.995	1.872	1.378	2.26	2.12	1.56

[4]KRF evaluates the quality of each journal every two years and determines the KCI index journals. Because many universities count only papers published in KCI journals in their faculty evaluations, professors try to publish their works in these journals.

TABLE 4—ANNUAL AVERAGE PUBLICATIONS PER PERSON IN SSCI JOURNALS (SOCIAL SCIENCES)

	Annual publication per person				Ratio (Education=1)		
Year	Education	Economics	Pub. Admin	Sociology	Economics	Pub. Admin	Sociology
1995	0.017	0.035	0.023	0.047	1.98	1.30	2.67
1996	0.023	0.074	0.018	0.075	3.23	0.80	3.28
1997	0.034	0.032	0.009	0.011	0.96	0.28	0.33
1998	0.024	0.047	0.004	0.037	1.96	0.18	1.55
1999	0.025	0.081	0.034	0.033	3.27	1.38	1.34
2000	0.035	0.032	0.018	0.033	0.92	0.51	0.96
2001	0.033	0.087	0.015	0.016	2.67	0.46	0.49
2002	0.032	0.065	0.020	0.008	2.06	0.64	0.25
2003	0.022	0.127	0.019	0.021	5.79	0.87	0.98
2004	0.024	0.185	0.030	0.079	7.79	1.24	3.32
2005	0.036	0.185	0.046	0.060	5.08	1.27	1.65
2006	0.057	0.216	0.037	0.095	3.77	0.65	1.66
2007	0.045	0.201	0.054	0.120	4.46	1.19	2.66
2008	0.054	0.185	0.046	0.181	3.40	0.84	3.32
2009	0.048	0.232	0.061	0.138	4.79	1.26	2.84
2010	0.050	0.290	0.048	0.100	5.76	0.96	1.99

0.27 in 1995, 0.515 in 1999 (the first year of phase I of BK21), and 1.5 in 2006 (the first year of Phase II of BK21), and close to 2 in 2010, the final year for which we have data. This is major increase. We can find similar patterns in other areas as well. In chemistry, the number of annual publications per person increased from 0.22 in 1995 to 1.87 in 2010.

The second easily recognizable aspect is the difference in the number of publications among science researchers. We can see this more clearly when we derive the quantity publication index relative to mathematics. The annual average per-person number of publications for physics and chemistry are more than twice that of mathematics for 2010. For biology, this figure exceeds 1.5. Under the assumption that the research efforts of different fields are not systematically different, it may be reasonable to interpret these differences largely as stemming from the difficulty of publication. To anyone who attempts to estimate research productivity, the most obvious implication of this difference is that one should compare the research productivity levels of scholars field by field.

We can find a similar pattern in the social sciences. When we derive the same index, specifically annual publications per person for several social science fields, we note how difficult it is to publish SSCI journal papers in Korea. As of 2010, the per-person SSCI journal publication is less than 0.3 for economics. We also found major differences in the numbers of publications among different fields. For example, the number of per-person SCI journal publications in economics is nearly six times greater than that for education in 2010.[5] Nonetheless, it should also be noted that the average annual number of publications for economics researchers is only one-seventh of that of physics researchers. Again we can say that there is no meaning in comparing the number of publications, for instance of an individual economist with that of a physicist.

[5]We suspect the same research effort in the social sciences. The research effort and difficultly with publication among different academic fields would be an interesting future research topic.

TABLE 5—NATIONAL-INTERNATIONAL PUBLICATION RATIO (SELECTED FIELDS)

	Natural Science				Social Science			
Year	Math	Physics	Chemistry	Biology	Education	Econ	Pub Admin	Sociology
1995	1.73	0.24	0.23	0.63	6.47	4.25	11.33	4.57
1996	1.71	0.19	0.25	0.72	6.83	2.42	18.10	3.00
1997	0.74	0.19	0.26	1.14	5.15	8.77	36.40	24.39
1998	0.75	0.15	0.32	0.65	9.98	5.35	81.83	7.94
1999	0.69	0.21	0.23	0.64	12.70	3.87	13.77	7.90
2000	0.56	0.14	0.26	0.49	9.78	9.92	21.63	6.74
2001	0.45	0.14	0.32	0.52	11.13	4.18	34.31	29.37
2002	0.95	0.11	0.30	0.50	13.81	5.78	26.78	59.77
2003	0.41	0.08	0.15	0.34	22.60	3.91	26.25	23.26
2004	0.54	0.11	0.15	0.29	22.72	2.11	17.05	5.99
2005	0.44	0.07	0.14	0.33	14.06	2.10	10.92	8.29
2006	0.33	0.09	0.14	0.27	10.38	2.29	14.29	6.74
2007	0.36	0.10	0.09	0.22	13.62	2.87	9.99	4.65
2008	0.37	0.10	0.10	0.22	13.20	2.94	11.34	2.42
2009	0.39	0.11	0.12	0.24	17.20	3.17	11.75	5.26
2010	0.34	0.11	0.12	0.24	21.09	2.82	16.93	8.37

We can also note differences in the ratios between national and international publications in different fields. In Table 5, we present the ratio between the national and international publications for different fields. In all of the natural science fields, this ratio decreases over time, meaning that researchers in Korea endeavor continually to publish their works in the international journals. For example, for physics and chemistry, this ratio is around 0.2 to 0.25 in 1995, meaning that Korean researchers in these fields published four to five times more papers in international journals than in national journals. In 2010, this ratio dropped to around 0.1. This is common in many of the natural sciences.

However, in the social sciences, the pattern is quite different. We note in Table 5 that most of the social science research output is published in Korea. The publishing ratios of national journals to international journals are 21.9 in education, 2.8 in economics, 16.9 in public administration, and 8.4 in sociology in 2010. In addition to economics, this ratio has increased since 1995, precisely the opposite of the natural sciences. Though not presented in the form of a table, it should be noted that very few papers in the humanities were published in international journals.

This is another piece of evidence that the comparison of individual researchers' productivity levels should be done within the same fields. Reflecting these differences in the publishing pattern, we will concentrate on papers published in international journals, when we examine the natural sciences and the engineering fields. In social sciences and humanities, we will examine both international and national journals.

B. *Framework for the Empirical Analysis*

We attempt to estimate the effects of different research funding schemes on the research productivity of professors using information about both project participants and non-participants.[6] To do this, we need to compare productivity

[6]It should be emphasized again that the aim of this section is not an evaluation of the BK21 or the WCU projects themselves. Rather, we want to compare the effect of these two projects on the productivity levels of the

changes before and after the research funding projects between the treatment groups and the comparison group. The obvious treatment groups are those professors who are participating in the project. Given that the participating professors are the best researchers in the leading graduate programs, it is only natural that they produce large amounts of research output before and after the project. However, the question should be, “Did their research output increase due to the government funding programs? What if these researchers did not have research funds such as BK21 or WCU?” Considering the research environment of Korean universities, the lack of such research funds mostly means a lack of good research assistants for many academic disciplines in the case of the BK21 program, and a lack of research assistants plus international cooperation in the case of the WCU program.

In an ideal situation, where we have information on the rank or scores of all the research teams at the selection stage, including those eliminated, we can apply a regression discontinuity approach to evaluate the causal relationships associated with these funds. Unfortunately, we do not have proper information about the selection process. What we do know about the selection process is that the most important selection criteria are the quantity and quality of the research produced by the faculty members. Thus, the first qualification of the control group is that it should be composed of professors that have shown the highest research performance levels among non-participants.

One can raise questions about whether this can be a proper control group, but this appears to be the only possible means of finding a control group of researchers that have shown similar research abilities, with the given dataset. Given the lack of information about individual researchers’ characteristics as closely related to research output levels, the output level itself would be the best criterion for selecting researchers who are close to the top researchers selected as actual funding recipients.

Another important fact about this control group is that the professors in this group may experience a loss of graduate students due to these research projects. Before the introduction of the first phase of the BK21 project in 1999, it was the convention in Korean academia, unlike that in the USA, that an undergraduate student of any university usually chose the same university for their graduate study if it had graduate program. However, with unprecedented increase in grants given to a few departments in each field, many prospective graduate students have chosen departments with BK21 funds. This caused a major decrease in the number of incoming students, especially those with better qualifications, into many graduate programs that were not selected.

Some professors argue that the entire structure of the BK21 and the WCU projects is counterproductive for their research owing to the slight pecuniary incentive and the high costs of the administrative burden. For example, they should write extensive research proposals to be selected, and once selected, they should write annual reports, both of which are quite time-consuming. Despite all of these

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participating professors. It must be noted that the main purpose of the BK21 project is to foster scholars from the younger generation through high-quality institutions. However, the research productivity of professors is a very important selection criterion; at the same time, it is the major performance indicator in annual reviews.

complaints, nearly all professors in top research schools create research teams and submit proposals. Along with pressure from the university, concern over losing research assistants was the major reason for this "revealed preference" for the large government funding project. It is very likely that researchers in the control group can receive many types of research funds. However, among many research funds in Korea, there are none other than the BK21 or the WCU that permit so large a portion of funds to go to graduate students.

This unique feature of the funding scheme — high compensation for graduate students or foreign scholars and little compensation for professors — can provide a useful policy experiment during which we can evaluate the importance of the research assistance and co-authors during the research process in different fields. By devising a control group of researchers with comparable abilities yet lacking a stable source of funding for research assistants, we can create a setting that compares the "BK21 project or the WCU project vs. all other research funding projects."

In the case of the WCU program, international cooperation or cooperation with foreign scholars is an additional treatment related to research assistance. Research teams receiving WCU funds must invite foreign scholars and should pay for them. Regardless of the contents of the cooperation, it is the most important feature that distinguishes WCU projects from BK21 projects.

To compare the relative efficiency of the two different projects, we ran two separate Regressions: one including BK21 project participants and non-participants in the sample and the other including WCU project participants and non-participants. More specifically, we obtain DID estimates from the following two equations.

$$PubIndx_{it} = \alpha_0 + \alpha_1 YBK + \alpha_2 DBK + \alpha_3 YBK * DBK + \Gamma_1 RCH_{it} + \delta Time + a_i + \varepsilon_{it}$$

$$PubIndx_{it} = \beta_0 + \beta_1 YWCU + \beta_2 DWCU_{it} + \beta_3 YWCU * DWCU + \Gamma RCH_{it} + \delta Time + a_i + \varepsilon_{it}$$

In the above equation $PubIndx_{it}$ denotes the index of the research output of individual i in year t. It is measured by the total number of annual publications adjusted by the number of co-authors, as explained in the previous section.[7]

YBK is a dummy variable, taking a value of 1 for the years of the BK21 project, specifically after 2006. *DBK* is a dummy variable taking a value of 1 for an individual participating in the BK21 project. The coefficient of this variable is the difference in the number of annual publications between participants and non-participants before phase II of the BK21 project. The coefficient of the interaction term *DYB*DBK*, α_3 is a DID estimator measuring the net effect of participating

[7]It must be noted that this index does not properly reflect the quality of the published works. We try to reflect the quality by limiting papers published in SCI, SSCI, AHCI, or KCI journals, but there are wide variety in the quality of those journals. It would be better if we can used the information on the impact factors. While not impossible, it is not easy to gather all information on the impact factors of different journals at different times. So we only use this quantitative index in this paper and leave the analysis of quality-adjusted measures of publication as a future research topic.

in the BK21 project.

In the same manner, *YWCU* is a dummy variable taking a value of 1 for the years of the WCU project, specifically the years 2009 and 2010. *DWCU* is a dummy variable taking a value of 1 for an individual participating in the WCU project. The coefficient of the interaction term *YWCU*DWCU*, β_3, is a DID estimator measuring the net effect of participating in the WCU project. By comparing two DID variables, we can determine which program works better with regard to the productivity of participating faculty members.

We add a time trend variable to control for the general increasing trend of publications. There are several reasons for the increasing trend in the number of publications in all academic fields. At the university level, an increasing number of universities have adopted a stricter faculty promotion system since the late 1990s. This induces more effort from the professors, leading to the increasing trend in research output. In the humanities and social sciences fields, the number of KCI journals increased in the 2000s, contributing to the trend of the increasing number of publications.

There should be certain control variables related to researchers' characteristics (RCH). Unfortunately, we do not have many variables in the dataset. The only variable we can use is the age of the researcher. To control for life-cycle aspects with reference to research activity, we add the age and squared age to the regression.

In the estimation, selecting proper control groups is the key issue. The control groups are composed of professors who earned their doctoral degree before 2006 and who produced highest annual average number of papers among the non-participants. The numbers of professors in the control groups are identical to the numbers of participating professors, specifically the sum of the number of professors participating in the BK21 or the WCU project. We use the same control group for both projects. The research performances in terms of the average annual publications from 1999~2010 are presented in Table 6.

It is clear that the annual average number of publications is higher in the treatment group in many fields. However, in some fields, such as mathematics and economics, the control group's number is higher. Between the two treatment groups, participants in the WCU program show higher productivity. It must be noted that there are fewer participants in the WCU program, and it is possible for the selection process to be more restrictive to the most productive researchers. It is also interesting to note that there are some very productive researchers who were not selected for participation in the WCU project. When we select the same small number of most productive researchers among non-participants of the WCU program, their average numbers of annual publications are much higher than those of the WCU participants in many fields. Typically, this number is more than double the former. This large gap implies that the productivity of professors is not the only selection criterion linked to the WCU program. For example, it is possible that some of the productive scholars work at less renowned institutions.

At this point, we consider the effect of research funding on the quality of graduate education programs. If we can distinguish the recipients of graduate funding from non-recipients, it would be relatively easy to infer the effect of the

TABLE 6—THE AVERAGE NUMBER OF ANNUAL PUBLICATIONS IN INTERNATIONAL JOURNALS (1999-2010)

	BK21 parti.	WCU parti.	non BK21[1)]	non WCU[2)]	non parti.[3)]
Physics	2.25 (132)	2.13 (31)	1.17 (132)	4.83 (31)	0.95 (147)
Biology	1.03 (153)	1.32 (20)	1.41 (153)	3.65 (20)	1.3 (162)
Chemistry	1.82 (158)	3.31 (32)	1.16 (158)	3.46 (32)	0.94 (169)
Mathematics	0.69 (61)	0.85 (7)	0.95 (61)	3.16 (7)	0.93 (62)
Electronic Engin.	1.41 (235)	3.32 (18)	0.63 (235)	4.51 (18)	0.57 (243)
Computer Science	0.76 (144)	1.91 (8)	0.41 (144)	2.9 (8)	0.41 (144)
Mechanical Engin.	1.15 (148)	1.2 (12)	0.57 (148)	4.6 (12)	0.56 (150)
Economics	0.39 (50)	0.18 (2)	0.45 (50)	2.38 (2)	0.44 (51)
Education	0.11 (40)	0.46 (3)	0.33 (40)	0.94 (3)	0.32 (42)
History	0.01 (25)	0.01 (3)	0.26 (25)	0.65 (3)	0.24 (28)

Note: 1) Non-BK21 refers to the groups of the most productive professors who do not participate in the BK21 program. Each group includes the same number professors as BK21 participants. It possibly includes those who participate in the WCU program. 2) Non-WCU refers to the groups of the most productive professors who do not participate in the WCU program. Each group includes the same number professors as WCU participants. It possibly includes those who participate in the BK21 program 3) Non Parti. represents the group of the most productive professors who participate neither in the BK21 nor the WCU program. Each group includes the sum of the BK and the WCU participants. Due to some professors who receive both funds, this number is not the same as the sum of the BK21 the WCU participants. 4) Numbers in parenthesis are the number of project participants.

projects by comparing the performances of the two groups. However, we do not have such information. It may be possible to identify institutions from which Korean PhD recipients earned their degrees, but there is no guarantee that they are actually fund recipients, as there are not a few individual non-recipients in the fund-receiving institution.

Given this difficulty in identifying true recipients, we use an indirect means of gaining information about the quality of education before and after the funding project. We look at the performances of PhD recipients who earned their doctoral degree from a Korean institution. That is, rather than asking whether the research funding projects enhance the productivity of recipients, we ask whether graduate funding programs lifted the general quality of graduate education in Korea. This is justifiable because this is the ultimate purpose of a funding project.

To answer this question, we compare the performances of doctoral recipients from Korean institutions with those from US institutions, which are widely believed to have highest graduate education quality in the world. More specifically, we compare the performance of doctoral degree holders from Korean institutions to those from US institutions before and after the establishment of the major graduate funding programs. We estimate the following simple equation for different cohort of doctoral degree holders.

$$PubIndx_{it} = \beta_0 + \beta_1 DKOR + \Gamma RCH + \delta Time + a_i + \varepsilon_{it}$$

The sample is composed of Korean doctoral degree holders who earned their doctorates in Korea or in the USA. In the above equation, *DKOR* is a dummy variable indicating doctoral degree holders who earned their doctorates in Korea. We estimate the equation for three different cohorts of doctoral degree holders: those who earned their doctorate (1) from 1995 to 2000, (2) from 2001 to 2005, and (3) after 2006. The coefficients of the dummy variable *DKOR* can be interpreted as the performance gap between doctoral degree holders from Korean institutions and those from US institutions. By examining the changes in the performance gap for these different cohorts, we can determine if the performance gap decreased after the funding projects for graduate programs began. The differences in the two estimates derived from different cohort samples can be considered as the DID estimator, indicating the change in the performance gap. If the research funding projects had positive effects, we will find a decreasing performance gap.

Let us first investigate the simple average numbers of annual publications. It is clear that Korean doctoral degree holders are more productive in recent years than in the past. In Table 7, we compare the same cohorts of Korean doctoral degree holders who earned their degree in Korea and in the US. There is not a clear pattern that can be applied to all the fields, but we note that in some fields, the performance gap has decreased. Physics is a very distinctive case in that recent graduates from Korean institutions are more productive than those from US institutions in terms of the number of papers. For the cohort of doctoral degree holders in physics who earned their degree between 1995 and 2000, the performance gap between US doctoral degree holders and their Korean counterparts is approximately 0.6 papers per year. The gap was narrowed to 0.4 papers for the 2001~2005 cohort. For the 2006~2010 cohort, doctoral degree holders from Korean institutes produce 0.5 more papers than those from US institutions, but in the humanities and social sciences, the performance gap has not been narrowed. As in the effect on the professors' productivity levels, the effects on graduate students are small for those in the humanities and social science fields. One possible reason is that in those academic disciplines, researchers tend to

TABLE 7—COMPARISON OF PRODUCTIVITY OF KOREAN DOCTORATE FROM US AND KOREAN INSTITUTION BY FIELDS - ANNUAL AVERAGE PRODUCTION OF PAPERS (INTERNATIONAL JOURNALS)

	1995~2000		2001~2005		2006~2010	
	US	Korea	US	Korea	US	Korea
Physics	1.23(34)	0.61(47)	1.13(13)	0.71(66)	0.30(11)	0.83(79)
Biology	0.55(59)	0.53(110)	0.73(29)	0.58(154)	0.88(14)	0.35(181)
Chemistry	0.71(31)	0.73(54)	1.08(39)	0.61(60)	0.62(29)	0.50(83)
Computer	0.35(49)	0.11(163)	0.40(33)	0.20(181)	0.40(18)	0.20(151)
Electronic	0.84(54)	0.19(227)	0.80(54)	0.33(194)	0.72(38)	0.40(165)
Mathematics	0.26(24)	0.21(30)	0.45(17)	0.51(44)	0.27(9)	0.26(29)
Mechanical	0.60(35)	0.16(102)	0.83(24)	0.38(76)	0.78(24)	0.34(104)
Architectural	0.26(18)	0.02(72)	0.46(14)	0.07(70)	0.06(10)	0.06(57)
Nuclear	0.61(4)	0.49(4)	0.67(1)	0.12(5)	0.00(1)	0.35(10)
Environmental	0.64(18)	0.20(39)	0.90(20)	0.21(40)	0.63(11)	0.36(31)
Food	0.86(13)	0.28(33)	0.85(16)	0.77(26)	1.05(14)	0.58(25)
Economics	0.20(42)	0.08(40)	0.16(41)	0.04(19)	0.13(15)	0.02(29)
Education	0.10(51)	0.01(131)	0.08(58)	0.01(180)	0.12(50)	0.01(162)
History	0.04(16)	0.01(105)	0.05(8)	0.01(73)	0.07(4)	0.00(60)
Sociology	0.04(22)	0.01(17)	0.18(9)	0.09(13)	0.23(12)	0.00(22)
Public Admin	0.06(9)	0.00(35)	0.05(16)	0.00(44)	0.19(11)	0.00(44)
English Lit	0.03(40)	0.00(55)	0.01(36)	0.00(28)	0.01(17)	0.02(22)

Note: Numbers in parenthesis are the number of doctoral degree holders in each category.

publish their works in national journals. We will assess this possibility in the next section, presenting the result of the regression analysis.

V. Empirical Results

A. *Comparing the Two Different Funding Schemes in terms of Research Productivity*

This section presents the major results from the estimations of many academic disciplines. We will present OLS, fixed effects and random effects estimation results. Before examining the results, it should be noted that previous researchers pointed out problems when using the DID method for evaluating research fund programs. For example, Jaffe (2002) warns that in some cases, the DID method can produce more biased results than a simple regression.[8] It would be better to interpret our result as the maximum estimates of the net effect.

Let us look at the result for physics, shown in Table 8. The dependent variable is the number of publications in SCI journals for each year. For physics, the number of BK participants is 132, and that for WCU is 31. Because there are some professors who participate in both projects, and the sum of the professors participating either one of the projects is 147; accordingly, the control group numbers 147. In Table 8, we can see very similar results for BK21 and WCU. The coefficient of the participating dummy has a positive sign, meaning that the participants had higher performance levels before the project. However, the year dummy had a negative sign, meaning that the increasing trend in publications was weakened. The coefficient of the key variables, specifically the interaction term of the participating dummy and the year dummy variable, take a positive sign but are statistically insignificant. Both participants in the project and non-participants produced more research papers in international journals after the project, and we cannot say that the participants are more productive due to the project.

Table 9 presents the DID estimates for several selected fields for which we have A relatively large number of fund recipients in the sample. Like physics, the DID estimators for the WCU project are insignificant in nearly all academic disciplines. The only exception is mechanical engineering. In this field, the DID estimators are positive and significant for both the BK21 and the WCU projects, but the absolute value is higher for the WCU program.

[8]The following quote from Jaffe (2002) explains this point clearly. "The limitation of this (DID) approach is that it only controls for time-invariant unobservables. To the extent that the agency can and does evaluate the proposed project distinctly from the proposing entity, the resulting selection bias is not eliminated by differencing. In addition, one could imagine other sources of unobserved performance differences that vary across individuals and time. For example, applicants may decide to enter the grant competition when they have been enjoying unusually good (or bad?) recent performance. Any unobserved variation of this kind makes the differences estimator biased; differencing eliminates the time-invariant but introduces a new error related to the deviation in the previous period from the applicant's 'normal' performance. Indeed, depending on the relative magnitude of time-invariant and time-varying individual effects, differencing could produce estimates that are more biased than simple regression estimates"

TABLE 8—THE EFFECT OF PARTICIPATING IN THE BK21 OR WCU PROGRAM - PHYSICS

	BK21			WCU		
	OLS	RE	FE	OLS	RE	FE
D_Parti	1.170***	1.068***		1.058***	0.970***	
	(0.138)	(0.224)		(0.169)	(0.321)	
P_Year	-0.450***	-0.502***	-0.533***	-0.509***	-0.539***	-0.547***
	(0.163)	(0.154)	(0.154)	(0.151)	(0.153)	(0.155)
Year*Parti	0.203	0.297	0.361	0.451	0.572	0.635
	(0.194)	(0.243)	(0.242)	(0.520)	(0.559)	(0.559)
Age	0.133***	0.247***	0.532***	0.126***	0.197**	0.430***
	(0.0388)	(0.0824)	(0.139)	(0.0377)	(0.0837)	(0.132)
Agesq	-0.00108**	-0.00235***	-0.00371**	-0.00111***	-0.00189**	-0.00271*
	(0.000439)	(0.000890)	(0.00157)	(0.000412)	(0.000911)	(0.00152)
Trend	0.166***	0.166***		0.160***	0.160***	
	(0.0248)	(0.0247)		(0.0168)	(0.0279)	
No. Obs	3,051	3,051	3,051	1,888	1,888	1,888
R^2	0.094		0.061	0.117		0.110
No. Scholars		279	279		178	178

Note: 1) The Variable "Parti" is the dummy variable take value if professors take part in the BK21 or WCU project 2) Numbers in the parenthesis are robust standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

TABLE 9—DID ESTIMATORS FOR SELECTED ACADEMIC DISCIPLINES (INTERNATIONAL JOURNALS)

	BK21			WCU		
	OLS	FE	RE	OLS	FE	RE
Physics	0.203	0.297	0.361	0.451	0.572	0.635
	(0.194)	(0.243)	(0.242)	(0.520)	(0.559)	(0.559)
Biology	-0.175	-0.225	-0.240	-0.182	-0.224	-0.263
	(0.110)	(0.162)	(0.167)	(0.395)	(0.387)	(0.392)
Chemistry	0.478***	0.527***	0.546***	0.163	0.275	0.346
	(0.131)	(0.166)	(0.168)	(0.464)	(0.584)	(0.577)
Computer	0.160*	0.151*	0.147*	-0.298	-0.238	-0.193
	(0.0905)	(0.0829)	(0.0837)	(0.805)	(0.672)	(0.678)
Electronic	0.452***	0.491***	0.506***	1.122	1.123	1.104
	(0.109)	(0.147)	(0.150)	(0.794)	(0.767)	(0.774)
Mathematics	-0.399***	-0.510**	-0.541**	-0.0419	-0.105	-0.123
	(0.149)	(0.239)	(0.250)	(0.383)	(0.403)	(0.413)
Mechanical	0.346***	0.426***	0.450***	0.912**	0.955**	0.975**
	(0.107)	(0.115)	(0.117)	(0.455)	(0.483)	(0.485)
Economics	-0.277***	-0.303***	-0.312***	-0.219	-0.234**	-0.238*
	(0.102)	(0.0928)	(0.0969)	(0.330)	(0.119)	(0.128)
Education	-0.0880	-0.136*	-0.169**	-0.00717	0.00777	0.0616
	(0.0645)	(0.0806)	(0.0827)	(0.224)	(0.0773)	(0.0629)
History	-0.198***	-0.198*	-0.241*	-0.180	-0.180	-0.200
	(0.0684)	(0.108)	(0.129)	(0.123)	(0.133)	(0.137)

Note: All coefficients are DID estimators. Numbers in parenthesis are robust standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

It is also notable that there are some cases, such as mathematics and economics, for which the DID estimators take negative values which are statistically significant. It is quite notable that the BK21 project appears to have an adverse effect on mathematics, unlike other science and engineering fields. One intuitive reason for this result is that research assistants in mathematics may not contribute much to their professors' research productivity levels. The same reasoning can be applied to the humanities and social sciences fields. In many humanities and social sciences fields, research assistants' roles are limited. However, in such science and engineering fields as chemistry and electronic engineering, where laboratory experiments are an indispensable part of the research, graduate students who serve as research assistants can greatly enhance the productivity of their professors.

We can summarize the results as follows. In terms of the research productivity levels of professors, BK21 had a more positive effect than WCU in certain science and engineering fields. Thus, we can say that BK21 was more favorable with regard to professors' research productivity levels than WCU. However, in the humanities and social sciences fields, neither project had a positive effect, and BK21 usually had a negative effect on the productivity levels of professors in these fields. The negative effects are relatively small in the WCU case. In a sense, WCU is less harmful than BK21 to professors' research productivity levels in the humanities and social science fields.

It is quite clear that grants to graduate students have the potential to increase the productivity of professors in some fields in which research assistants make large contributions to the research process. Nonetheless, it is difficult find an intuitive explanation for the weak effect of the WCU project on the research productivity of participating professors in the science and engineering fields.

Moreover, it must be noted that the main purpose of these funding programs is not to increase the productivity of professors. Rather, the main purpose is to increase the quality of graduate studies. Next, we will examine the changes in the productivity of Korean doctoral degree holders from Korean institutions.

B. *The Effect of Government Research Funds on the Productivity of Graduate Students*

At this stage, we examine the performance gap between doctoral degree holders educated in Korea and those educated in the USA. Table 10 presents the estimates of the performance gap in certain academic fields from a random effects model. For the 1995~2000 cohort, doctoral degree holders from US institutions produced more papers than those from Korean institutions in all academic disciplines. The situation does not change much for the 2000~2005 cohort, but for the 2006~2010 cohort, the performance gaps are either narrowed or, as in the case of physics and nuclear engineering, doctoral degree holders from Korean institutions produced more papers.

This clear sign of a narrowing gap in these cases can be considered as indirect evidence that major funding projects have somehow succeeded in lifting up the educational quality in Korean graduate schools in some science and engineering fields.

However, there are good reasons to suspect that the sample selection process could be a decisive factor that made the performance gap between the US doctoral degree holders and Korean doctoral degree holders smaller in recent years. Consider the case of doctoral degree holders from the US institutions who work in Korea. Doctoral degree holders who earned their degrees ten years earlier and stayed in the US for some years showed good performances and thus enjoyed

TABLE 10—COMPARISON OF THE PRODUCTIVITY OF KOREAN DOCTORAL DEGREE HOLDERS FROM US AND KOREAN INSTITUTIONS BY FIELD - REGRESSION RESULTS

	International Journals (SCI or SSCI)			National Journals (KCI)		
	1995~2000	2001~2005	2006~2010	1995~2000	2001~2005	2006~2010
Physics	-0.635***	-0.418	0.532**	-0.00564	-0.0465	0.0309**
	(0.246)	(0.311)	(0.259)	(0.0252)	(0.0861)	(0.0122)
Biology	-0.0858	-0.0989	-0.612	0.0532*	0.0638**	-0.183
	(0.0958)	(0.156)	(0.515)	(0.0323)	(0.0305)	(0.210)
Chemistry	-0.154	-0.439**	-0.124	0.0328	0.0438*	0.0244
	(0.186)	(0.191)	(0.160)	(0.0437)	(0.0229)	(0.0284)
Computer	-0.238**	-0.195**	-0.164*	-0.0740**	-0.0430	0.0998
	(0.0962)	(0.0806)	(0.0896)	(0.0334)	(0.0657)	(0.0642)
Electronic	-0.604***	-0.411***	-0.379***	-0.124**	0.00322	0.128**
	(0.172)	(0.142)	(0.139)	(0.0518)	(0.0562)	(0.0569)
Math	-0.122	0.0254	-0.0278	0.110**	0.0557	0.0464
	(0.0776)	(0.152)	(0.101)	(0.0528)	(0.0340)	(0.0285)
Mechanical	-0.415***	-0.302*	-0.518***	-0.0715	0.145**	0.0318
	(0.110)	(0.171)	(0.161)	(0.0468)	(0.0741)	(0.0699)
Archit.	-0.235***	-0.364**	0.00738	-0.378***	-0.467*	0.0411
	(0.0832)	(0.166)	(0.0399)	(0.146)	(0.244)	(0.102)
Nuclear	-0.0481	-0.622***	0.543***	0.218***	0.0611	0.0609
	(0.269)	(0.0532)	(0.185)	(0.0771)	(0.0581)	(0.0558)
Environ.	-0.394**	-0.575***	-0.220	-0.121	-0.143	0.275*
	(0.174)	(0.184)	(0.266)	(0.112)	(0.154)	(0.154)
Food	-0.496**	0.159	-0.390*	-0.0735	-0.0830	0.212**
	(0.243)	(0.331)	(0.208)	(0.112)	(0.116)	(0.103)
Economics	-0.0619	-0.109***	-0.109*	0.142	0.0376	0.0763
	(0.121)	(0.0380)	(0.0599)	(0.213)	(0.0789)	(0.132)
Education	-0.0837***	-0.0701***	-0.111***	-0.0988	0.0872	0.0591
	(0.0278)	(0.0218)	(0.0338)	(0.0935)	(0.0718)	(0.123)
History	-0.0291	-0.0379	-0.0734	0.0540	-0.247	-0.0322
	(0.0212)	(0.0400)	(0.0665)	(0.0987)	(0.182)	(0.150)
Sociology	-0.0337	-0.114	-0.221**	-0.0790	-0.226	0.209
	(0.0206)	(0.149)	(0.0987)	(0.109)	(0.164)	(0.193)
Pub. Admin	-0.0688*	-0.0508**	-0.190*	0.0991	-0.377***	-0.0821
	(0.0408)	(0.0231)	(0.101)	(0.165)	(0.120)	(0.214)
English Lit	-0.0295**	-0.00711	0.0198	-0.394***	-0.318***	0.0382
	(0.0123)	(0.00528)	(0.0176)	(0.0823)	(0.101)	(0.149)

Note: Numbers in the parenthesis are robust standard errors.
*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

good chances to return to Korea and be hired at prestigious institutions. Their performances would be better than doctoral degree holders who earned their degrees ten years earlier, when there was little government funding for graduate students.

Now, let us consider the younger cohort. The best young researchers among those who just earned their degree in the USA had a greater chance to stay in the US than less able researchers. Thus, it is possible that we are comparing the average doctoral degree holders from Korean institutions with less able doctoral degree holders from US institutions. In the meantime, the large increase in research funding for graduate studies could cause many students stay in Korea rather than to choose to study abroad. Thus, the decrease in the performance gap may largely reflect a decrease in the ability gap among graduate students rather than a decrease in the educational quality gap in graduate schools.

Considering these selection effects, a more proper comparison group should be a group of Korean doctoral degree holders who studied and then stayed in the USA, which is simply not possible with the current dataset. We need to gather information on Korean scholars staying in the USA. While it is very likely that selection bias prevails, it is not likely that all of the decrease in the performance gap can be attributed to selection effects, especially in certain cases, such as physics.

Meanwhile, in the humanities and social sciences fields, the performance gap measured by the number of publications in international journals does not change much after the major graduate funding projects. The results are similar for national journals. The positive effect on the research productivity of graduate students after graduation is not clearly seen yet in many academic disciplines.

C. *Summary and Policy Implications*

Here, we summarize the empirical results and derive some policy implications from them. Table 11 summarizes the empirical results presented in the previous section. The BK21 project had a positive effect in some natural science and engineering fields. The effect of the WCU projects is usually very weak. The only exception is mechanical engineering, where both the BK21 and the WCU had positive effects, with WCU having a stronger effect. In some academic disciplines that WCU project works better than BK21 because WCU project is less harmful, rather having overall positive effects. There are several possible reasons for this weak effect. Most of all, the emphasis on international cooperation does not appear to be a wise way to spend research funds efficiently.

All things considered, the BK21 funding scheme appears to be a good program in that it can raise the research productivity of professors while training future researchers in many natural science and engineering fields. It also appears to be a better funding scheme than the WCU scheme. In some academic fields in which research assistants provide important input to the research process, it appears only natural that a direct subsidy to research assistants will have noticeable effects.

However, we must worry about the negative effects of funding projects in certain fields. It is difficult to believe that a funding project can have negative effects, but we can conceive of several possible reasons for this. For example, we suspect that

TABLE 11—SUMMARY OF RESULTS

	BK21 Eff	WCU Eff	Relative Effectiveness	Educ Quality
Physics	–	–	Similar	○
Biology	–	–	Similar	–
Chemistry	○	–	BK21 over WCU	○
Mathematics	×	–	WCU over BK21	–
Electronic Engin.	○	–	BK21 over WCU	○
Computer Science	○	–	BK21 over WCU	○
Mechanical Engin.	○	○	WCU over BK21	–
Economics	×	×	Similar	–
Education	×	–	WCU over BK21	–
History	×	–	WCU over BK21	–

Note: ○ Positive effect, — No Effect, × Negative Effect the selection of the recipients was not based on the individual professors' productivity levels in some fields. For example, the restriction that more than 70% of faculty members should join the research team can induce some free-riding unproductive recipients to participate in the project. It is also possible that some of the recipients made their maximum effort before the program started, only to be selected, while they have little incentive to work as diligently after the selection.

The small pecuniary incentive for faculty members can also be a reason for the small effect. Regardless of the reason, there should be wiser ways to spend research funds more efficiently. Specifically, for certain fields in which these funds do not have positive effects on either professors' or graduate students' research productivity levels, we need to think about other schemes.

For example, we can consider economics. How can we interpret the negative effects of the BK21 and the WCU projects shown in economics? Do we need a large research group in economics? Is it the best way to educate researchers of the next generation to give grants only to students in two or three graduate schools? Why should we distribute grants to graduate students based on their professors' or departments' merit, instead of their own merits?[9] These questions lead us to think that there could be better ways to enhance the productivity of current professors while providing a higher quality education for the next generation of researchers in diverse academic disciplines.

In terms of the educational quality, it is challenging to derive policy suggestions. We find that the performance gaps between doctoral degree holders from Korean institutions and those from US institutions have narrowed in certain natural science and engineering fields. However, there are many academic disciplines for which these performance gaps are maintained with all government subsidies. Hence, it is difficult to reach the conclusion that the major funding projects enhanced the overall quality of graduate education, especially for many social science and humanity fields. Even in fields that succeeded in decreasing the gaps, there are reasons to suspect that it was the selection process rather than the educational quality which served as the main cause of the dragging down of the performance gap.

Nonetheless, it is not likely that selection bias explains the overall decrease in the gap. It should also be noted that the decreasing performance gap is more evident in such fields as chemistry, electronics engineering, and computer science, where the BK21 project showed a positive effect on professors' productivity levels as well. This can be interpreted as a sign that research grants to graduate students ultimately enhanced their research productivity, perhaps through the cooperation with their professors. This in turn implies that the performance levels of the current generation and the next generation are highly correlated. If this is indeed the case, the best means of enhancing the research productivity of the next generation of researchers would be to induce higher productivity in the current generation regardless of the field of study.

[9]In a different context, Conley *et al.* (2013) recently raised a similar concern with US data. They find that the research rankings of top economics departments are a surprisingly poor predictor of the subsequent research rankings of their PhD graduates.

VI. Concluding Remarks

In this paper, we have examined the effects of research funds to graduate schools on the research productivity of professors by comparing the quantity of publications between projects participants and non-participants. The most notable result is that the effects of the BK21 and WCU projects on professors' research productivity levels differ for different fields. For BK21, we find a positive effect in many natural science and engineering fields. In these fields, the effects of the WCU are generally weaker than those of the BK21 project. The restriction on fund use may be the main cause of this weak effect. There is no reason to believe that international cooperation is the key element in enhancing research productivity for the current generation or future generation of researchers. Rather, it appears that one of the key factors behind the increase in research productivity is help from research assistants in academic fields for which experiments are indispensable during the research process.

While the empirical results are quite clear and have strong policy implications, there are obvious limitations. Most of all, the lack of information about a proper control group is the main problem in the empirical analysis. Specifically, it appears to be challenging to correct any possible selection bias with the current dataset. Moreover, our measure of research productivity has a clear limitation in that it places too much weight on quantity. We need to incorporate information on the quality aspects of research productivity in the analysis.[10] In the case of the research productivity of graduate students, we need better datasets that can identify recipients of funding projects among Korean doctoral degree holders. All of these limitations are naturally suggesting future research directions.

Despite these instances of a lack of empirical rigor due to data limitations, the differences in the effects among academic disciplines should be taken seriously. For some fields for which the BK21 or WCU projects had weak or negative effects, we should think about revising the funding schemes to reflect the characteristics of the research process of the corresponding academic disciplines.

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[10]There are many people in Korean academia who offer the criticism that the government and universities place too much weight on the quantity of the research products, and that as a result there are not as many challenging and influential studies as desired.

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